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Economics of open-access fisheries: A case of factors affecting the revenue of coastal or inshore longline fisheries in Pakistan

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This study attempts to determine the effects and strength of association of several techno-economic factors affecting the revenue for a sample of open-access inshore longline boats in the coastal waters of Pakistan. Prior research focuses on two non-parametric test statistics, namely Spearman's rank correlation and Kendall's coefficient of concordance for the estimation of coefficients due to the non-normal distribution of the data. The estimated values of correlation coefficients for the catch ($\rho_{\text{revenue, catch}} = 0.721$, $\tau_b = 0.567$), trips ($\rho_{\text{revenue, trips}} = 0.707$, $\tau_b = 0.574$) and crew ($\rho_{\text{revenue, crew}} = 0.715$, $\tau_b = 0.587$) indicates a strong positive relationship on revenue generation. Similarly, the intercorrelations between the crew on the catch ($\rho_{\text{crew, catch}} = 0.56$, $\tau_b = 0.45$) and crew on trips ($\rho_{\text{crew, trips}} = 0.55$, $\tau_b = 0.47$) also show a strong positive association in Spearman's rank correlation while the Kendall's correlation shows a weak relationship. Furthermore, the estimated values of engine speed show a very weak association with revenue ($\rho_{\text{revenue, engine}} = 0.25$, $\tau_b = 0.18$). Conclusively, the revenue increases with the increase in fish catch, sea trips and the number of crew members on board. Additionally, the results of engine speed signify that the coastal fishery is a less fuel-efficient and economically viable business for the fishermen community in the country.

[Keywords: Coastal or inshore, Kendall's coefficient of concordance, Multiple correlations, Open-access, Revenues, Spearman's rank correlation]

Introduction

Coastal or inshore fisheries have been playing a significant role in the upsurge of production levels from fisheries by the development of modernization of fishing fleets and gears over the last five decades. Despite its significance, the information regarding the impact of the artisanal or small-scale fisheries sector to income generation and economic growth has been scarce in many developing countries¹. In fact, the shore-based fisheries are considered to be the most sustainable in comparison to the industrial or large-scale fisheries². Notwithstanding, the marine capture fisheries of Pakistan has been playing a pivotal role in the national economy with the steady export potential of 131,000 tons with value \$226 m since 2011^(ref. 3). However, the country's fishery is divided into three major sub-sectors, viz. coastal or inshore, industrial offshore and deep-sea fisheries. Besides, the territorial range of coastal or inshore fisheries was about 12 nautical miles (NM) from the shoreline while mainly gillnet and longline gears were used during certain fishing seasons⁴ (Fig. 1). Indeed, the inshore longline fishery was done by the medium to large fiberglass and wooden boats locally termed as "Dhoonda". Specifically, the overall length of

the boats was more than 35ft with an operational range of 8-14 days of fishing trips and catches various kinds of pelagic and demersal fishes⁵. On the contrary, the shore-based fisheries have been ignored by the fishery managers, policy-makers and scientists due to the paucity of economic and biological data. In this regard, the work of Kolding *et al.*⁶ has documented the importance of coastal fisheries by discussing the relationship of small-scale fisheries from the conservation and governance perspective. Moreover, several studies also indicated the profitability and production capabilities of small-scale fisheries⁷. Similar studies also revealed the profitability of coastal fisheries by documenting the relationship of fish species with respect to gear specification⁸. Apart from these, the work of Asiyah *et al.*⁹ reported the factors affecting the inshore fisheries in terms of technical efficiency.

So far, however, there has been little discussion in the literature about the techno-economic factors affecting the income generation in coastal or inshore fisheries. Therefore, the main purpose of this research is to examine the effects and strength of the association of several techno-economic factors affecting the shore-based fisheries revenue in Pakistan by providing a thorough

perception of the current economic situation of coastal fisheries. Additionally, the several statistical methods have been recommended for the economic and biological assessment of fisheries. To assess the effects and associations between variables, the rank correlation is more suitable¹⁰. For this purpose, the multiple correlation analysis with the estimation of two ranks based non-parametric correlation coefficients, the Spearman's rho and Kendall's tau corrected for tied ranks being used to measure the effect sizes of each determinant on revenue^{11,12}. The overall aim of this study is to help the fishery managers and policy-makers to upgrade the National Fisheries Policy (NFP) from the economic standpoint and to pay attention on the economic feasibility, governance and implementation of fishery laws to operate the coastal fisheries in an effective manner which can lead to fisheries sustainability.

Materials and Methods

Sampling and data collection

For the study, comprehensive pre-designed survey questionnaires which were specifically intended to collect

the technical and economic information pertaining to operational costs, amount of catch landed in kilograms, number of crews on board, trip duration and engine speed in terms of horsepower with the fishermen operating in the coastal waters of Pakistan were used. However, the fleet's orientation data has been acquired from the "*Handbook of Fisheries Statistics*" published by the "*Marine Fisheries Department, Government of Pakistan*"¹³. The field survey was carried out from two locations, viz., Baba Bhit Island and Karachi Fish Harbour (KFH) during the period of non-fishing months of June and July 2016. Additionally, the fishermen were asked for opinions about the current stock status of major coastal pelagic and demersal fish species and their perception about the management of coastal fisheries. Seventy-two large boats (N = 72) which are locally termed as *Dhoonda* of different lengths ranging from 35 to 40 ft were randomly selected from two sampling sites in this study¹⁴.

Selection of variables and analytical tools

Per trip income or revenue from the fishing operation was selected as the key variable in terms of

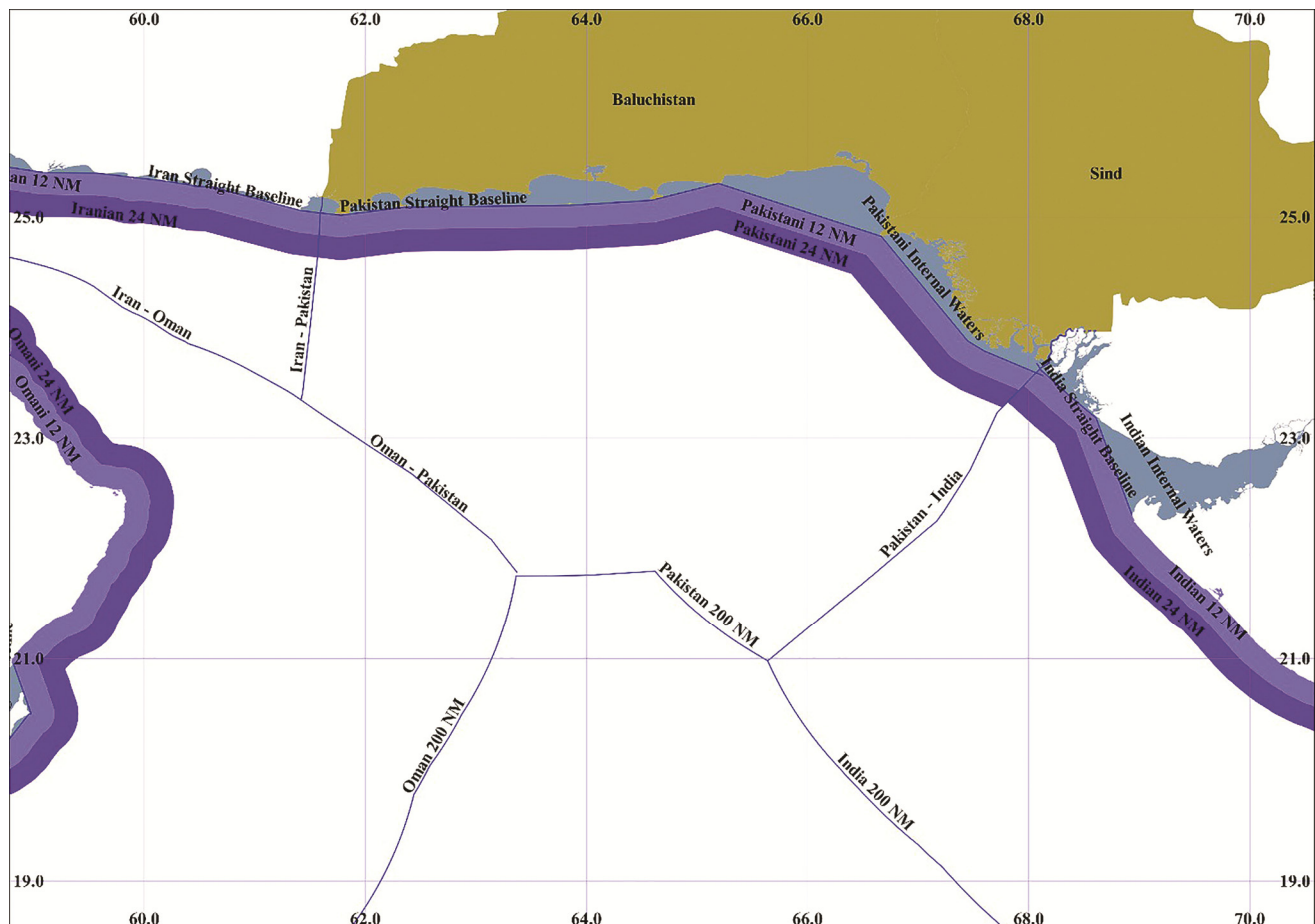


Fig. 1 — Map showing the maritime zones of Pakistan

Pakistan Rupees (PKRs). In addition, other variables selected were per trip catch or landed fish quantity in kilograms (kg), number of crew members on board, and engine speed in terms of horsepower (HP).

JASP version 0.8.5.1 (2018) computer program was used for the rank-based multiple correlation analysis¹⁵. While the R version 3.4.2 (2017-09-28) statistical software was used for the graphical representation of rank correlation coefficients and flow of fishing operation in coastal or inshore fisheries¹⁶. In addition to this, the open-source Quantum Geographical Information System (QGIS) software was also used to generate a coastal map of Pakistani territorial waters¹⁷.

Data analysis

To measure, the effects or strength of the relationship between two continuous variables, the coefficients of correlation served as the index of effect sizes¹⁸. Albeit the fact that there were several commonly used correlation measures, but we used two different methods of non-parametric rank-based multiple correlation coefficient analysis, such as Spearman's rho (ρ) corrected for tied ranks and Kendall's tau (τ) coefficient of concordance, due to the non-normal distribution and the presence of tied values among the variables of the techno-economic data of the coastal fisheries^{19, 20}.

Spearman's rank-order correlation equation (corrected for tied ranks)

Rank-based correlations have been the most effective and meaningful way to describe the dependencies among several input variables in the presence of outliers and distribution free (non-normal) data schemes²¹. The work of Hauke & Kossowski²² has reported the importance of Spearman rank correlation to assess the strength and association between two variables when the data have been violating the assumptions of Gaussian distribution. Supporting the rank-based correlation methods, the Spearman²³ himself accentuated the use of rank correlation when dealing with two series of measurements comparable to each other. However, the basic notion behind the rank correlation is that each variable ranked separately from lowest to the highest order. To get the degree or magnitude of the correlation between two variables, the calculated values of the sum of the square of the difference between two ranked variables will be large or vice versa²⁴. Furthermore, Cohen *et al.*²⁵ and Zar¹¹ documented the two different forms of mathematical expressions of Spearman's rank order correlation or rho(ρ) to assess the strength of correlation between two variables.

The equation that describes the standard Spearman's rank order correlation uncorrected for tied variables is as follows:

$$\text{Rho } (\rho) = \frac{1-6\sum d^2}{n(n^2-1)} [\text{Zar}^{11}] \quad \dots (1)$$

Where, d = Difference in the ranks of pair observations in each variable.

The other equation expressing the Spearman's rank order correlation corrected for tied variables can be written as:

$$\text{Rho } (\rho) = \frac{(n^3-n)/6 - \sum d_i^2 - \sum t_x - \sum t_y}{\left[\frac{\sqrt{n^3-n}}{\sqrt{6-2t_x}} \right] \left[\frac{\sqrt{n^3-n}}{\sqrt{6-2t_y}} \right]} \quad \dots (2)$$

Where, $\sum t_x$ = Sum of all the x value of ties and $\sum t_y$ = Sum of all the y-values of ties.

From the equation corrected for tied data, we can compare the conformity and disparity among several input variables from the side by side ordering lists of ranks.

Kendall's coefficient of concordance equation (corrected for tied ranks)

Kendall²⁶ has proposed a new measure of rank correlation termed as Kendall's coefficient of concordance or tau (τ). Furthermore, a widely accepted class of the rank-based correlation method, an alternative to Spearman's rho and played a significant role in the nonparametric test statistics²⁷. However, Kendall's tau has represented the magnitude of conformity (concordance) and disparity (discordance) between the two columns of rank data with a plausible range of results lie on a scale from -1 to 1^(ref. 20). Notably, Kendall²⁸ has suggested the algorithm of concordant and discordant pair while stating that the two largest ranks of the X-variable linked with two largest ranks of the Y-variable, then XY values were said to be concordant. Similarly, when the two smaller ranks of X-variable are associated with two largest ranks of the Y-variable, then the pair is said to be a discordant. Besides this, Kendall's tau manipulates the concept of Spearman's rho of ranking the variables while directly using the idea of concordant and discordant pairs in the description of correlation measures.

The general mathematical form of tau can be written as follows:

$$\text{Kendall's tau} = \frac{C-D}{C+D} [\text{Jinyuan et al.}^{29}] \quad \dots (3)$$

Where, C is the number of concordant pairs, and D is the number of discordant pairs.

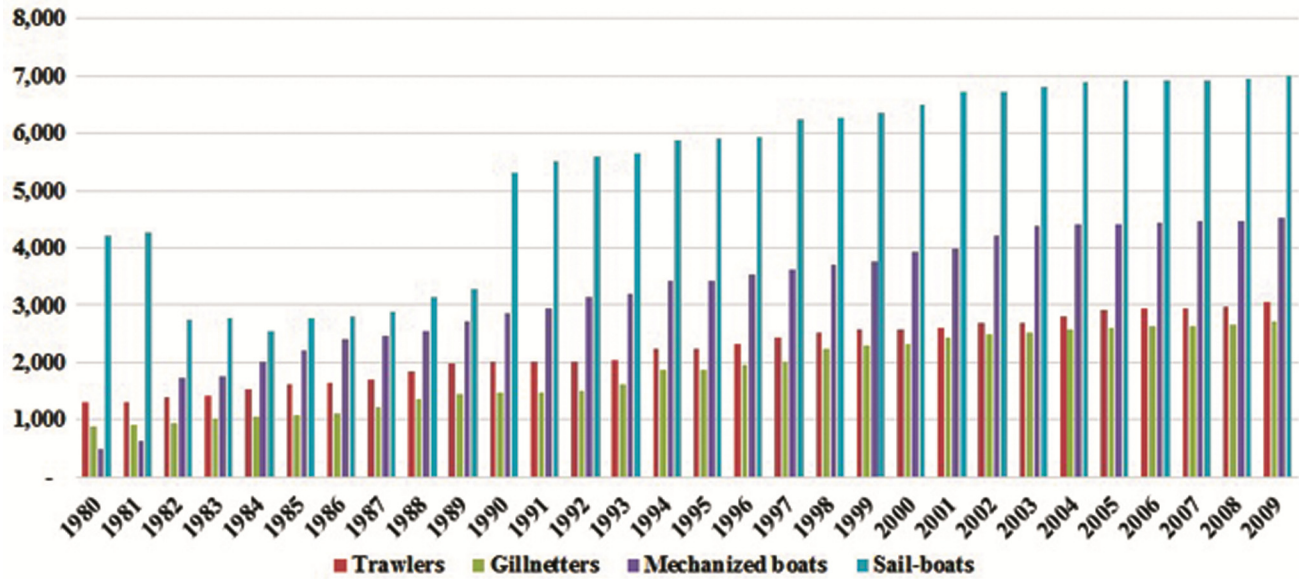


Fig. 2 — Fleets orientation in Pakistan from 1980-2009

Table 1 — Summary statistics for sampling boats

Statistic	N	Mean	St. Dev.	Min	Max
Revenue	72	392,144.9	50,585.87	300,833	494,681
Catch	72	1,483.361	361.533	1,030	2,000
Trips	72	13.069	1.142	12	15
Crew	72	12.611	1.205	11	15
Engine	72	190.264	6.230	180	200

Note: Revenue = Rupees/trip, Catch = Kilograms/trip, Trips = Number of days at sea/year, Crew = Number of fishermen onboard, Engine = Boat speed in horsepower, respectively.

To date, several coefficients of concordance have been reported in hypothesis testing known as tau-a (τ_a), tau-b (τ_b) and tau-c (τ_c)³⁰. Correspondingly, Kendall's tau-a has measured the covariance between the distributions of two random variables being studied and easily interpretable³¹. Analogous to tau-a, Kendall's tau-b is another sophisticated approach to measure the association between rank ordered variables and explicitly designed when the data have tied values³². However, the tau-b is similar to Leo Goodman and William Kruskal Gamma (γ) and has the range from -1 to 1^(ref. 33).

Generally, the Kendall's tau-b can be expressed mathematically (sample version) by the following formula:

$$\tau_{b} = \frac{C-D}{\sqrt{\frac{n(n-1)}{2-T_x}} \sqrt{\frac{n(n-1)}{2-T_y}}} \quad \dots (4)$$

Where, C = Number of concordant pairs; D = Number of discordant pairs; T_x = Number of pairs

tied only on the X-variable; and T_y = Number of pairs tied only on the Y-variable.

From the above equation $n(n-1)/2$ is equivalent to Concordant (C), Discordant (D), and Tied pairs on X (T_x), Tied pairs of Y (T_y) and both (T_{xy}).

Results

The general descriptive statistics of variables for the rank-based multiple correlation analysis are summarized in Table 1. From Table 1, it is notable that the mean revenue generated by the inshore longline boats per trip was 392,144.9 (Rs) with a range of 300,833 to 494,681 (Rs) Pakistani Rupee, and an average catch of 1,483.361 kg ranging from 1,030 to 2,000 kg per trip. Similarly, the annual average operational sea trips are 13 each 8 days long, and the minimum and maximum crew members onboard ranged from 11 to 15 during each trip throughout the year. Whereas, the average observed engine speed of small-scale longline boats is 190 (HP). Additionally, the trends in fleet's orientation data can be represented from Figure 2. However, the flow of inshore fishing operations to generate revenues in fisheries system of Pakistan and direction of correlations between the several determinants can also be visualized from Figure 3. To demonstrate the effect size and association of several factors affecting the revenue of shore-based longline fisheries of Pakistan, an estimated Spearman's rank based correlation coefficient (ρ) or rho corrected for tied ranks is presented in Table 2. The estimated values of the Spearman rank correlation coefficient between

Table 2 — Computed values of Spearman rank order correlations (ρ) corrected for tied ranks between catch, trips, crew, engine and revenue

		Revenue	Catch	Trips	Crew	Engine
Revenue	Spearman's rho	—				
	<i>p</i> -value	—	***			
Catch	Spearman's rho	0.721	—			
	<i>p</i> -value	< .001	***			
Trips	Spearman's rho	0.707	0.468	—		
	<i>p</i> -value	< .001	< .001	—		
Crew	Spearman's rho	0.715	0.558	0.546	—	
	<i>p</i> -value	< .001	< .001	< .001	—	
Engine	Spearman's rho	0.254	0.130	0.198	0.065	—
	<i>p</i> -value	0.031	0.278	0.096	0.588	—

Note: * $p < .05$; ** $p < .01$; *** $p < .001$. Spearman's rho represents the corrected Spearman rank correlations of tied variables, respectively.

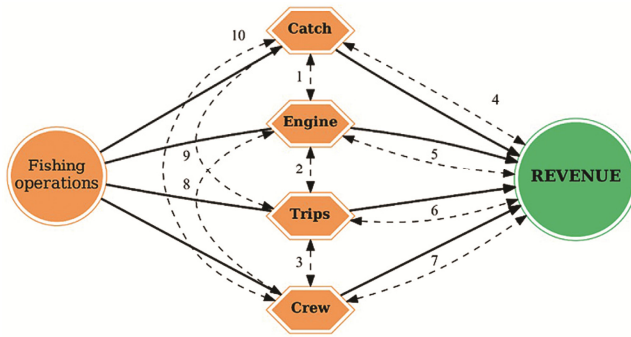


Fig. 3 — Flow diagram shows the direction of correlations between several techno-economic factors

revenue and catch is ($\rho_{\text{revenue, catch}} = 0.721$), revenue and trip is ($\rho_{\text{revenue, trips}} = 0.707$) and between revenue and crew is ($\rho_{\text{revenue, crew}} = 0.715$), which indicates that there is a very strong positive relationship between these variables. Similarly, the intercorrelations between the catch on trips ($\rho_{\text{catch, trips}} = 0.47$), catch on crew ($\rho_{\text{catch, crew}} = 0.56$) and trips on crew ($\rho_{\text{trips, crew}} = 0.55$) which indicate the moderate positive relationship among these variables. Further, it is evident from the results that all the variables showed a strong tendency towards statistical significance ($p < 0.0001$) at the standard 5 % level of significance. Alternatively, the engine speed or horsepower on revenue is ($\rho_{\text{revenue, engine}} = 0.24$), which indicates the weak relationship of engine speed on the revenue and showed a marginal trend ($p = 0.03$) towards statistical significance. Additionally, for visual representation of the dependencies of several variables on revenue and among each other, the correlation plot of Spearman's rank correlation can be seen from Figure 4.

Apart from Spearman's rank correlation, the results obtained from the analysis of Kendall's coefficient of concordance corrected for tied ranks (tau-b) are presented in Table 3. It is apparent from the results of

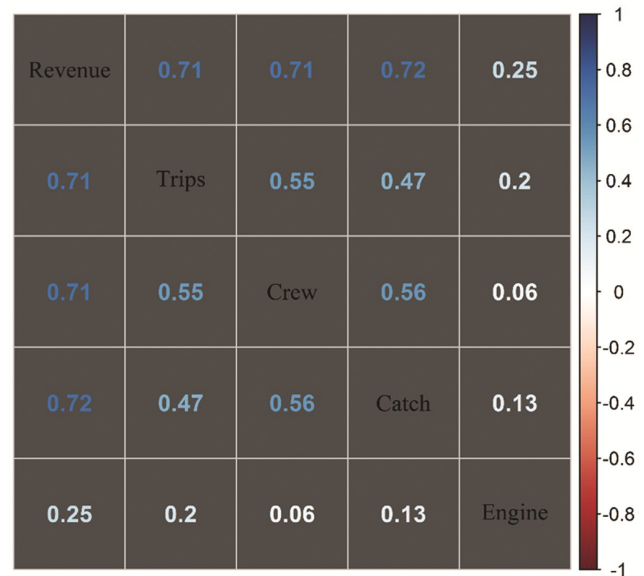


Fig. 4 — Visual representation of Spearman's rank order correlation

the study, that there is a strong, positive correlation between variables like catch, trips and crew on the revenue and statistically significant from zero ($\tau_b = 0.567, p < 0.001$), ($\tau_b = 0.574, p < 0.001$) and ($\tau_b = 0.587, p < 0.001$) respectively. Even so, the intercorrelations between the variables such as catch on trips, catch on the crew and trips on the crew were moderate positive correlation and also show significance beyond doubt ($\tau_b = 0.377, p < 0.001$), ($\tau_b = 0.453, p < 0.001$) and ($\tau_b = 0.47, p < 0.001$). From the results of Kendall's tau-b, it has been found that the engine speed or horsepower also show very weak correlation and marginal significance on revenue ($\tau_b = 0.18, p = 0.027$) corresponding to Spearman's rank correlation. Also, the results can be visualized from correlation plot of Kendall's coefficients of concordance (Fig. 5).

Table 3 — Computed values of Kendall's tau (τ_b) correlations of concordance between catch, trips, crew, engine and revenue

		Revenue	Catch	Trips	Crew	Engine
Revenue	Kendall's tau-b	—				
	<i>p</i> -value	—	***			
Catch	Kendall's tau -b	0.567	—			
	<i>p</i> -value	< .001	***			
Trips	Kendall's tau-b	0.574	0.377	—		
	<i>p</i> -value	< .001	< .001	***		
Crew	Kendall's tau-b	0.587	0.453	0.470	—	
	<i>p</i> -value	< .001	< .001	< .001	—	
Engine	Kendall's tau-b	0.182	0.096	0.153	0.053	—
	<i>p</i> -value	0.027	0.246	0.098	0.556	—

Note: * $p < .05$; ** $p < .01$; *** $p < .001$. Kendall tau B represents the Kendall correlations adjusted for tied ranks, respectively

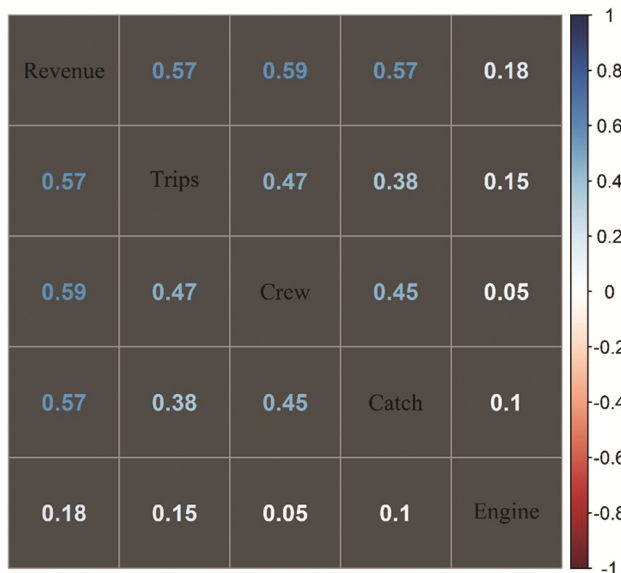


Fig. 5 — Visual representation of Kendall's tau correlation of concordance

Discussion

The economic incentive has been the major driving force for the fishermen which are primarily led by the financial returns and profit maximization from the fishing operations in the fishery³⁴. Conversely, the economic insecurity (lower incomes) and susceptibility of fishery resources (lower catches) have been worse by the open-access settings in most artisanal or small-scale fisheries. Therefore, the fishermen have no alternative but to continue the fishing over and beyond the biological and economical limits³⁵. The main concern of the paper was focused on the economic aspects of inshore longline fisheries. However, the particular attention is being paid to the several factors affecting the revenue of shore-based fisheries in Pakistan.

The global contribution of artisanal or small-scale fisheries to the world's total landed value were about 30 % (revenue generated at dockside) and played a

significant role to employ 90 % of the world's total capture fishermen³⁶. Despite the significance, the inshore fisheries were usually ignored among the policy-makers in comparison to industrial fishing. However, the boats operating in the small-scale category have assured the higher catch rates and maximum profits³⁷. Similarly, the values of rank-based correlations of Spearman's and Kendall's correlation well supported the notion of the strong positive relationship of catch on revenue, which indicates that the profits will increase with increasing catches, particularly in small-scale longline fisheries.

From the economic perspective, the number of fishing days or fishing trips has the greater influence on the profitability of fishing boats due to rise in cost and revenues¹. Therefore, the study suggested the strong positive relationship of fishing trips on revenue in results of both non-parametric tests, which implies that revenue significantly increases with the increase of fishing trips or vice versa. Equally important is the fact that the economic motivation is the key for the fishermen to operate in the sea such as the information regarding resource availability and revenues generated from the previous trips³⁸. Likewise, our results identify a very strong positive relationship between revenue and crew participation in small-scale fisheries, which indicates that profit increases with increasing number of crews during the fishing operation. One possible reason to explain is that many inshore fisheries are labor-intensive and are comparatively cheaper to hire which can substantially increase the profitability of boats³⁹. Yet, the results from the analysis of the interdependence of engine speed or horsepower (HP) on revenue and all the combinations of variables show a very weak correlation. The rationale behind is that the engine speed is directly linked to fuel consumption. Given the fact that, greater engine speed results in higher

fuel consumption during the fishing operations and significantly increase the cost of fishing and reduced revenues with less viable fisheries in terms of profitability⁴⁰. Therefore, our results supported the fact that small-scale, longline fisheries have been less fuel-efficient and engine speed has less or very weak effect on the revenue⁴¹.

Above all, apart from intercorrelations of several factors affecting the revenue, our results also show very strong positive and moderate associations in case of catch on the crew, the crew on trips and catch on trips respectively (Tables 2 & 3). From the technical point of view to date, improved quality of fishing is a subject of concern among the producers and consumers. Therefore, the efforts have been made while designing the fishing boats, maximize the number of crews and installation of equipment's to reduce the handling time of sorting and storing on board⁴². Similarly, the results from the analysis imply that higher catches significantly increase the amount of work onboard and more crew needed to reduce the workload and produce good quality fishery products to the consumers. To our best knowledge, this is the first study that investigates the economic aspects by empirically quantifying the several techno-economic variables affecting the revenues of inshore longline fisheries of Pakistan. For instance, these findings may help us to understand the conceptual premises of current economic and biological situation in the shore base fisheries system of the country.

Conclusion

Conclusively, the present study set out to determine the effects and the association of the several techno-economic factors affecting the revenue of inshore longline fisheries in Pakistan. However, the results of this investigation show that the effect of catch, trips, and crew have a strong positive relationship to the revenue in both methods of rank based correlation, which implies that if catch, trips, and crew increases then revenue significantly increases or vice versa. Notwithstanding, the most significant finding to emerge from the study is that engine speed or horsepower has a very weak relationship to the revenue generation, which implies that engine speed is directly linked to fuel consumption and more fuel is needed to complete the fishing operations resulting in higher fishing costs and lower incomes which led the inshore fisheries less economically viable. In fact, weak correlation suggests that still small-scale, longline fisheries in Pakistan is less fuel-efficient and

economically feasible business for the fishermen operating in the coastal waters of the country⁴³. Considerably more research work will be needed to determine the social, economic and technical nexus of inshore fisheries and fishermen in the country.

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Conflict of Interest

The authors have no conflicts of interest to declare.

Author Contributions

The authors likely to certify that, the MTH & MYT had contributed towards the preparation of this paper such as conceptualization, data collection, data analysis, funding acquisition, manuscript drafting and supervision; SBH & TRP contributed in editing the contents of writing and guidance; and MTK contributed in modifications, suggestions and review.

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